we may recognize the agreements and differences of the various forms; he then points out the general purposes of classification and the principles of nomenclature, the principles of comparative anatomy and their application to the study of extinct animals, and the general facts of geographical distribution. His third chapter is devoted to a brief sketch of the classification of animals, the fourth to their development and reproduction, and the fifth to certain general observations on the food and instincts of certain species, mimicry, &c. In this chapter also the author discusses the question of the nature and possible origin of species. We most heartily recommend this little volume as a first book of zoology.

Mr. Wilson's work, which carries the teaching much further, and is really a student's manual, is also an excellent work of its kind. Mr. Wilson covers pretty nearly the same ground as Prof. Newton, although of course he enters into much more detail; and we have to compliment both authors on the same characteristic of their work—namely, the total freedom from prejudice with which they have discussed those unsettled questions which at present divide naturalists.

PROCEEDINGS OF LEARNED SOCIETIES.

ROYAL SOCIETY.

February 4, 1875.—Joseph Dalton Hooker, C.B., President, in the Chair.

"Remarks on Professor Wyville Thomson's Preliminary Notes on the Nature of the Sea-bottom procured by the Soundings of H.M.S. 'Challenger.'" By William B. Carpenter, M.D., LL.D., F.R.S.

The extreme interest of two of the questions started and partly discussed in Professor Wyville Thomson's communication will be deemed, I trust, a sufficient reason for my offering such contributions as my own experience furnishes towards their solution.

The first of these questions is, whether the *Globigerinæ*, by the accumulation of whose shells the *Globigerina*-ooze is being formed on the deep-sea bottom, live and multiply *on* that bottom, or pass their whole lives in the superjacent water (especially in its upper stratum), only subsiding to the bottom when dead.

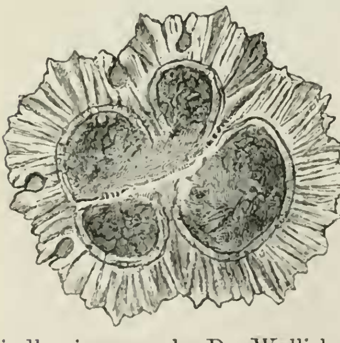
Having previously held the former opinion, Prof. Wyville Thomson states that he has now been led to adopt the latter, by the results of Mr. Murray's explorations of the surface and subsurface waters with the tow-net—which results concur with the previous observations of Müller, Häckel, Major Owen, and others, in showing that *Globigerinæ*, in common with many other Foraminifera, have a pelagic habitat; while the close relation which they further indicate between the surface-fauna of any particular locality and the materials of the organic deposit at the bottom, appears to Prof. Wyville Thomson to warrant the conclusion that the latter is altogether derived from the former.

Now without in the least degree calling in question the correctness of these observations, I venture to submit, *first*, that they bear a different interpretation, and, *second*, that this interpretation is required by other facts, of which no account seems to have been taken by Prof. Wyville Thomson and his coadjutor. In this, as in many other instances, I believe it will prove that the truth lies between two extreme views. That the *Globigerinæ live on the bottom only* is a position clearly no longer tenable; but that they live and multiply *in the upper waters only*, and only sink to the bottom after death, seems to me a position no more tenable than the preceding: and I shall now adduce the evidence which appears to me at present to justify the conclusion (I refrain from expressing myself more positively, because I consider the question still open to investigation), that whilst the *Globigerinæ* are pelagic in an earlier stage of their lives, frequenting the upper stratum of the ocean, they sink to the bottom *whilst still living*, in consequence of the increasing thickness of their calcareous shells, and not only continue to *live* on the sea-bed, but probably *multiply* there—perhaps there exclusively.

That there is no *à priori* improbability in their doing so, is proved by the abundant evidence in my possession of the existence of Foraminiferal life at abyssal depths. The collections made during the 'Porcupine' Expeditions of 1869 and 1870 yielded a large number of those *Arenaceous* types which construct their "tests" by the cementation of sand-grains only to be obtained on the bottom; and these were almost the only Foraminifera, except *Globigerinæ* and *Orbulinæ*, which came up in the 2435-fathoms dredging. Again, many Foraminifera, both arenaceous and shelly, were brought up from great depths, attached to shells, stones, &c., that *must* have lain at the bottom. Further, among the "vitreous" Foraminifera, the most common deep-sea types, except those of the Globigerine family, were *Cristellarians* with shells so thick and massive as to be (it may be safely affirmed) incapable of being floated by the animals which form them; while among the "porcellaneous" Foraminifera, the *Biloculinæ* and *Triloculinæ* were equally distinguished by a massiveness of shell, which seemed to forbid the idea that they could have floated subsequently to that stage of their lives in which this massiveness had been acquired.

Of the existence of living *Globigerinæ* in great numbers in the stratum of water immediately above the bottom, at from 500 to 750 fathoms depth, I am able to speak with great positiveness. It several times happened, during the Third Cruise of the 'Porcupine' in 1869, that the water brought up by the water-bottle from immediately above the *Globigerina*-ooze was quite turbid; and this turbidity was found (by filtration) to depend, not upon the suspension of amorphous particles diffused through the water, but upon the presence of multitudes of young *Globigerinæ*, which were retained upon the filter, the water passing through it quite clear. The *thin shells* of these specimens, exhibiting very distinct pseudopodial orifices, contrasted strongly with the larger and thicker shells of the specimens brought up by the sounding-apparatus from the bottom immediately beneath, in which the shells were thick and those orifices obscure. It is obvious that if this extraordinary abundance of Globigerine life in the bottom-water was the result of subsidence from the surface or sub-surface stratum, and was merely preparatory to the deposition of the shells on the sea-bed, there should have been a correspondence in size and condition between the floating shells and those lying on the bottom immediately beneath them; whereas no contrast could be more complete, the impression given by the superficial aspects they respectively presented having been fully confirmed by subsequent careful investigation.

Prof. Wyville Thomson and Mr. Murray, who notice this contrast, attribute it to the *death* of the shells which have subsided to the bottom—being apparently unaware that the observations of Dr. Wallich, with which my own are in entire accordance, leave no reasonable ground for doubt that it is a consequence of their continued *life*. For it is clearly shown, by making thin transparent sections of the thick-shelled *Globigerinæ* (an operation which needs a dexterity only to be acquired by long practice, and which is much facilitated by an ingenious device invented by Dr. Wallich *), that the change of external aspect is due to the remarkable *exogenous deposit* (a rudiment of the "intermediate skeleton" of higher Foraminifera) which is formed, after the full growth of the *Globigerina* has been attained, upon the outside of the proper chamber-wall—so completely masking its pseudopodial orifices, that Prof. Huxley at one time denied their existence. This deposit is not only many times thicker than the original chamber-wall, but it often contains flask-shaped cavities opening from the exterior, and containing sarcode prolonged into it from the sarcodic investment of the shell. Illustrations of this curious structure are given by Dr. Wallich in figs. 17 and 18 of plate vi. of his 'North-Atlantic Sea-bed;' and I here subjoin a representation of it,



Section of Shell of *Globigerina*, showing the distinction between the original proper wall of the chambers and the secondary exogenous deposit, with the flask-shaped cavities in the latter opening externally and containing sarcode like that which fills the chambers.

kindly given me by Dr. Wallich twelve years ago, which further

* Ann. & Mag. of Natural History, 1861, viii. p. 58.

shows that the specimen from which it was taken had both its chambers and the flask-shaped cavities of the exogenous deposit filled with sarcode not distinguishable in any respect from that of the floating specimens. From these important observations (which had not been made public when the sheet of my 'Introduction to the Study of the Foraminifera' comprising the Globigerine family passed through the press, but which I have myself subsequently confirmed in every particular) it seems an almost inevitable inference that the subsidence of the *Globigerinæ* to the bottom is the consequence, not of their death, but of the increasing thickness and weight of their shells, produced by living action. As long as the number of segments continues to increase, the carbonate of lime separated by the sarcodic body from the circumambient water goes to form the walls of additional chambers; but when this chamber-formation ceases (which usually occurs when the shell consists of either 12 or 16 segments), it is applied to thicken the walls of the chambers already formed; and from the rapid subsidence of the *Globigerinæ* taken up from the sea-bottom when thrown into a jar of sea-water, it seems to me inconceivable that they can be floated by their animal inhabitants when once the exogenous deposit has attained any considerable thickness.

That the *Globigerinæ* which have subsided to the bottom continue to live there, is further indicated by the condition of the sarcodic contents of their shells. In any sample of *Globigerina*-ooze that I have seen brought up by the dredge or the sounding-apparatus, part of the shells (presumably those of the surface-layer) were filled with a sarcode body corresponding in condition with that of Foraminifera known to live on the sea-bed, and retaining the characteristic form of the organism after the removal of the shell by dilute acid. As Dr. Wallich pointed out ('North-Atlantic Sea-bed,' p. 139), the sarcode of these is viscid, and inclined to coalesce again when crushed; the shell has a vivid but light burnt-sienna colour; and sarcodic bosses, like retracted pseudopodia, are distinguishable upon its exterior. The only misgiving I ever had in regard to the living condition of the *Globigerinæ* presenting these characters, was caused by the absence of any pseudopodial extensions; and this source of doubt has been now removed by the statement of Prof. Wyville Thomson, that no pseudopodia have ever been observed by Mr. Murray to be put forth by the *Globigerinæ* captured in surface-waters.—In the same sample will be found shells distinguishable from the preceding by their dingy look and greyish colour, by the want of consistence and viscidity in their sarcode contents, and by the absence of any external sarcodic investment; these are presumably dead. Other shells, again, are entirely empty; and even when the surface-stratum is formed of perfect *Globigerinæ*, the character of the deposit soon changes as it is traced downwards. "The sediment," as was correctly stated by Prof. Wyville Thomson, "gradually becomes more compact; and a slight grey colour (due, probably, to the decomposing organic matter) becomes more pronounced, while perfect shells of *Globigerina* almost disappear, fragments become smaller, and calcareous mud, structureless and in a fine state of division, is in greatly preponderating proportion" ('Depths of the Sea,' p. 410). These facts seem to me to mark very strongly the distinction between the *living* surface-layer and the *dead* sub-surface layer, and to show that there is nothing in the condition of the Deep Sea that is likely to prevent or even to retard the decomposition of the dead sarcode bodies of *Globigerinæ*. We know that oxygen is present in Oceanic water, even to its abyssal depths, in sufficient proportion for the maintenance of animal life; and what suffices for this, must be adequate to promote the decomposition of organic matter. There is, moreover, a significant indication of the undecomposed condition of the sarcode bodies of the *Globigerinæ* of the surface-layer, in the fact that they serve as food to various higher animals which live on the same bottom. This was first pointed out by Dr. Wallich, who found that the contents of the stomachs of the *Ophiocomæ* brought up in his 1260-fathoms sounding consisted of a number of fresh-looking *Globigerinæ* more or less broken up, minute yellow amorphous particles, and a few oil-globules ('North-Atlantic Sea-bed,' p. 145). And I have subsequently verified his statement in many other cases *.

It seems to me clear, from the foregoing facts, that the *onus probandi* rests on those who maintain that the *Globigerinæ* do *not* live on the bottom; and such proof is altogether wanting. The most cogent evidence in favour of that proposition would be furnished by the capture, floating in the upper waters, of the large thick-shelled specimens which are at present only known as having been brought up from the sea-bed. And the capture of such specimens would only prove that even in this condition the *Globigerinæ* can float; it would not show that they cannot also live on the bottom.

That the *Globigerinæ* not only *live*, but *propagate*, on the Sea-bottom, is indicated by the presence (as already stated) of enormous multitudes of very young specimens in the water immediately overlying it. And thus all we at present know of the life-history of this most important type seems to lead to the conclusion, that whilst in the earlier stages of their existence they are inhabitants of the upper waters, they sink to the bottom on reaching adult age, in consequence of the increasing thickness of their shells, that they propagate there (whether by gemmation or sexual generation is not known), and that the young, rising to the surface, repeat the same history.

I now proceed to show that the relation between the surface-fauna and the bottom-deposit is by no means so constant as Prof. Wyville Thomson and Mr. Murray affirm it to be.

* Thus Man indirectly draws sustenance from the *Globigerinæ*; for the Cod which he fishes on the Faroe Banks chiefly live on the *Ophiocomæ* which swarm there, these again on the *Globigerinæ*, whilst the *Globigerinæ* seem to draw their sustenance from the organic matter universally diffused through sea-water, making it a *very* dilute broth!

It may be taken as proved that there is no want of Foraminiferal life in the Mediterranean. Prof. W. C. Williamson long ago pointed out that the "white mud" of the Levant is mainly a Foraminiferal deposit; I found a similar mud covering the bottom along the Tripoli coast; Mr. J. Gwyn Jeffreys has dredged Foraminifera in abundance in the Bay of Spezzia, Captain Spratt in the Ægean, Oscar Schmidt in the Adriatic, and I myself at various points in the Western basin along the northern coast of Africa. That Foraminifera, especially *Globigerinæ*, abound in its surface-water at Messina, is testified by Häckel in the passage cited by Prof. Wyville Thomson; and when it is considered how large an influx of Atlantic water is constantly entering through the Straits of Gibraltar, and is being diffused throughout the Mediterranean basin, and how favourable is its temperature-condition, it can scarcely be doubted that, if the doctrine now upheld by Prof. Wyville Thomson were correct, the deposit of *Globigerina*-shells over the whole bottom-area ought to be as abundant as it is in the Atlantic under corresponding latitudes. Yet I found the deeper bottoms, from 300 fathoms downwards, entirely destitute of Globigerinæ as of higher forms of animal life; and this was not my own experience only, but was also that of Oscar Schmidt, who made a similar exploration of the Adriatic. In my first visit to the Mediterranean, in the 'Porcupine' (1870), many hundredweight of the fine mud brought up by the dredge from great depths in the Western basin were laboriously sifted, and the siftings carefully examined, without bringing to light more than a stray drift-shell here and there. And in my second visit, in the 'Shearwater' (1871), I examined all the samples of bottom brought up by the sounding-apparatus from great depths in the Eastern basin, with the same result—giving all the more care to this examination, because Capt. Nares (probably through not having kept separate in his mind the results of the deeper and of the shallower soundings which he had previously made in the Mediterranean) assured me that I *should* find minute shells imbedded in the mud.

I can see no other way of accounting for the absence of *Globigerina*-ooze from the bottom of the Mediterranean, save on its shallow borders, than by attributing it to the unfavourable nature of the influences affecting the *bottom-life* of this basin—that is to say, the gradual settling-down of the fine sedimentary deposit which forms the layer of inorganic mud everywhere spread over its deeper bottom, and the deficiency of oxygen and excess of carbonic acid which I have shown to prevail in its abyssal waters giving them the character of a stagnant pool—these influences acting either singly or in combination.

Another fact of which Prof. Wyville Thomson is fully cognizant, and to which he formerly attached considerable importance as indicative of the bottom-life of the *Globigerinæ*, is unnoticed in his recent communication: I refer to the singular limitation of the *Globigerina*-ooze to the "warm area" of the sea-bed between the North of Scotland and the Faroe Islands. It will be recollected by those who have read my 'Lightning' and 'Porcupine' Reports on the exploration of this region, that whilst the whole upper stratum, from the surface to a depth of from 100 to 150 fathoms, has the temperature of the warm flow coming up from the S.W., and whilst this temperature falls so gradually in the "warm area" with increase of depth as to be still as high as 43° Fahr. at a depth of 600 fathoms, it falls so suddenly in the "cold area" between 150 and 300 fathoms, that the whole of its deeper stratum has a temperature below 32°, the bottom temperature descending in some parts to 29°·5. Now on this "cold area" I never found a single *Globigerina*, the bottom consisting of sand and gravel, and the Foraminifera brought up from it being almost exclusively those which form arenaceous tests. The "warm area," on the other hand, is covered with *Globigerina*-ooze to an unknown depth, its surface-stratum being composed of perfect shells filled with sarcode, whilst its deeper layers are amorphous. Near the junction of the two areas, but still within the thermal limit of the "warm," sand and *Globigerina*-ooze are mingled—this being peculiarly noticeable on the "*Holtenia*-ground," which yielded a large proportion of our most noteworthy captures in this locality. Now, if the bottom-deposit is dependent on the life of the surface-stratum, why should there be this complete absence of *Globigerina*-ooze over the "cold area," the condition of the surface-stratum being everywhere the same? I was myself formerly disposed to attribute it to the depression of bottom-temperature; but as it has now been proved by the 'Challenger' observations in the Atlantic that *Globigerina*-ooze prevails over areas whose bottom-temperature is but little above 32°, this explanation can no longer be accepted. And I can see no other way of accounting for it than by attributing it to the drift of the cold underflow, carying away the *Globigerinæ* that are subsiding through it towards the deep basin of the Atlantic, into which I believe that underflow to discharge itself. Prof. Wyville Thomson, however, denies any sensible movement to this underflow, continuing to speak of it as "banked up" by the Gulf-stream *, which here (according to him) has a depth of 700 fathoms; and this very striking example of want of conformity between the surface-fauna and the bottom-deposit consequently remains to be accounted for on his hypothesis.

The other of Prof. Wyville Thomson's principal conclusions, as to which I have rather a suggestion to offer than an objection to take, relates to the origin of the "red clay" which he found

* See his 'Depths of the Sea,' p. 400. That there is a *lateral* pressure of the one flow against the other, just as there is a lateral pressure of the Labrador Current against the Gulf-stream on the North-American coast (producing the well-known "cold wall"), is sufficiently obvious from their relative distribution on the bottom of the channel. But it seems to me perfectly clear that the effect of this pressure is simply to *narrow* the glacial flow, and at the same time to increase its velocity. The most westerly point to which we traced it was near the edge of the Faroe Banks; and there (as Prof. Wyville Thomson himself pointed out to me at the time) the movement of the bottom-water was

covering large areas in the Atlantic, and met with also between Kerguelen's Island and Melbourne. Into this red clay he describes the *Globigerina*-ooze as graduating through the "grey ooze;" and he affirms this transition to be essentially dependent on the depth of the bottom. "Crossing," he says, "from these shallower regions occupied by the ooze into deeper soundings, *we find universally* that the calcareous formation gradually passes into, and is replaced by, an extremely pure clay, which occupies, speaking generally, all depths below 2500 fathoms, and consists almost entirely of a silicate of the red oxide of iron and alumina. . . . . . The mean maximum depth at which the *Globigerina*-ooze occurs may be taken at about 2250 fathoms; the mean depth at which we find the transition grey ooze is 2400 fathoms; and the mean depth of the red-clay soundings is about 2700 fathoms. . . . . . . We were at length able," he continues, "*to predict the nature of the bottom from the depth of the soundings with absolute certainty* for the Atlantic and the Southern Sea." And from these data he considers it an indubitable inference "that the red clay is essentially the insoluble residue, the *ash*, as it were, of the calcareous organisms which form the *Globigerina*-ooze after the calcareous matter has been by some means removed." This inference he considers to have been confirmed by the analysis of several samples of *Globigerina*-ooze, "always with the result that a small proportion of a red sediment remains, which possesses all the characters of the red clay." Prof. Wyville Thomson further suggests that the removal of the calcareous matter may be due to the presence of an excess of carbonic acid in the bottom-waters, and to the derivation of this water in great part from circumpolar freshwater ice, so that, being comparatively free from carbonate of lime, its solvent power for that substance is greater than that of the superjacent waters of the ocean. He might have added probability to his hypothesis if he had cited the observations of Mr. Sorby as to the increase of solvent power for carbonate of lime possessed by water under greatly augmented pressure*.

Greatly struck with the ingenuity of this hypothesis, I turned to Prof. Wyville Thomson's tabular statement of the facts in detail, and must own to a great feeling of surprise at the want of conformity of these details with the assertions of universality and certainty of prediction which I have italicized in the above extracts.

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evidenced by the rounding into pebbles of what was elsewhere angular gravel. But it is even more conclusively shown by a comparison of the two serial soundings taken in the "cold area" (Nos. 52 and 64), which proves that the glacial stratum *flows up a slope* in the former position (just as the cold understratum does in the Florida Channel), which it could not do unless it were in movement. That we did not trace the outflow of this cold stream into the great basin of the Atlantic, was simply, as I believe, because we were prevented from ascertaining the bottom-temperature on the line which I expected that flow to take after surmounting the ridge.

* Proceedings of the Royal Society, vol. xii. p. 538.

Thus in the deepest sounding in the whole Atlantic (that of 3875 fathoms, taken on the voyage from St. Thomas to Bermuda), as well as in the next two soundings of 2960 and 2800 fathoms respectively (the average of the three being 3211 fathoms), the bottom was "grey ooze;" whilst in the next three soundings of 2850, 2700, and 2600 fathoms respectively (the average of the three being 2716 fathoms, or nearly 400 fathoms less than the preceding) the bottom was of "red clay." Between Bermuda and the Azores, again, there were six successive soundings between 2700 and 2875 fathoms, in which the bottom was "grey ooze."

It is clear, then, that no constant relation exists between depth and the nature of the bottom. If not only eight ordinary soundings whose average was almost exactly 2800 fathoms, but the extraordinarily deep sounding of 3875 fathoms, gave a bottom of "grey ooze," it surely cannot be "an ascertained fact that wherever the depth increases from about 2200 to 2600 fathoms, the modern chalk formation of the Atlantic and other oceans passes into a clay."

Now, if this "red clay" had the character of an ordinary river-silt, it would be quite conformable to my Mediterranean experience to regard it (as Prof. Wyville Thomson himself was at first disposed to do) in the light of a derivative from the land, diffused through the ocean-water and slowly settling down over particular areas, to which it might be determined by the prevalent direction of the bottom-flow, which would greatly depend in its turn upon the ridge-and-valley conformation of the sea-bed. And the presence of a small proportion of this material in the ordinary *Globigerina*-ooze, whilst, where it is deposited in quantity, there are neither entire *Globigerinæ* nor their disintegrated remains, would be perfectly consistent with the known destructive effect of the slow subsidence of a muddy sediment on many forms of animal life*.

But I agree with Prof. Wyville Thomson in thinking that the remarkable uniformity of this deposit, coupled with its peculiar composition, indicates a different derivation; and the suggestion I have to offer is based on its near relation in composition, notwithstanding its great difference in appearance, to *Glauconite*—the mineral of which the green sands that occur in various geological formations are for the most part composed, and which is a silicate of peroxide of iron and alumina.

It is well known that Prof. Ehrenberg, in 1853†, drew attention to the fact that the grains of these green sands are for the most part, if not entirely, *internal casts* of Foraminifera—the sarcodic bodies of the animals having been replaced by glauconite, and the calcareous shells subsequently got rid of, either by abrasion or by some solvent which does not attack their contents. It was soon afterwards shown by Prof. Bailey (U. S.) that in certain localities

* See my 'Shearwater' Report in Proceed. Roy. Soc. 1872, vol. xx. p. 584.

† "Ueber den Grünsand und seine Erläuterung, etc.," in Abhandl. der königl. Akad. der Wissensch. zu Berlin, 1855, p. 85.

a like replacement is going on at the present time, the chambers of recent Foraminifera being occasionally found to be occupied by mineral deposit, which, when the shell has been dissolved away by dilute acid, presents a perfect internal cast of its cavities. By the application of this method to Mr. Beete Jukes's Australian dredgings, my coadjutors, Messrs. W. K. Parker and T. Rupert Jones, obtained a series of internal casts of most wonderful beauty and completeness, on which I have based my interpretation of the organic structure of *Eozoon canadense*. Having myself examined in the same manner a portion of the Foraminiferal sand dredged by Capt. Spratt in the Ægean (kindly placed in my hands by Mr. J. Gwyn Jeffreys), I have found that it yielded a great variety of these beautiful models, not only of the bodies of Foraminifera, but also of the sarcodic network which interpenetrates the calcareous network of the shell and spines of Echinida*.

Alike in Mr. Jukes's and in Capt. Spratt's dredgings, some of these casts are in *green* silicates and some in *ochreous*, corresponding precisely to the two kinds of fossil casts described by Prof. Ehrenberg. The difference I presume to depend upon the degree of oxidation of the iron; but as these casts are far too precious to be sacrificed for chemical analysis, I cannot speak with certainty on this point.

As it is only in certain limited areas of the sea-bottom that this replacement of the sarcodic bodies of Foraminifera by mineral deposit is met with, it has always seemed to me next to certain that there must be some peculiarity in the composition of the sea-water of those areas (produced, perhaps, by the outburst of submarine springs highly charged with ferruginous silicates) which gives to them a capability that does not exert itself elsewhere; and this now seems yet more probable from the circumstance that, notwithstanding the vast extent over which the 'Challenger' soundings and dredgings have been prosecuted, only two or three cases of the kind have been noted—those, namely, of the "greenish sands" brought up from 98 and 150 fathoms in the region of the Agulhas Current and in one or two other localities. It is a fact of peculiar interest, moreover, that the calcareous shells should have here disappeared, just as they have done in ordinary green-sand—and this, too, although the depth was so small as altogether to forbid the idea that their disappearance is due to any solvent process brought about by the agencies to which Prof. Wyville Thomson attributes the removal of the calcareous deposit generated by Globigerine life.

Now, in the residue left after the decalcification of Capt. Spratt's dredgings, I noticed a number of small particles of *red clay*, some of them presenting no definite shape, whilst others approximated sufficiently closely in form and size to the green and ochreous

* Of these I hope to be able, ere long, to give a detailed account, in illustration of the similar models of the animal of *Eozoon* obtained by the decalcification of its serpentine lamellæ.

"internal casts" to induce me to surmise that these also had been originally deposited in the chambers of Foraminifera—their material being probably very nearly the same, although its state of aggregation is different. And if this was their real origin, I should be disposed to extend the same view to the red clay of the 'Challenger' soundings; for a strong *à priori* improbability in the supposition that this is the "ash" of the shells themselves is created by the fact that we have no knowledge (so far as I am aware) of the presence of any such ash in calcareous organisms of similar grade. It is certainly not proved by the analyses of *Globigerina*-ooze quoted by Prof. Wyville Thomson, since this (supposing it to be free from any extraneous admixture) may have contained many shells partially or completely filled with such deposit. The only analysis that could prove it would be either that of shells of floating *Globigerinæ*, which may be presumed to be alive, or of those found in the surface-layer of the *Globigerina*-ooze, which (whether living or dead) have their chambers filled with sarcode.

I submit, then, that if the red clay is (as I am disposed to believe) a derivative of the *Globigerina*-ooze, its production is more probably due to a *post mortem* deposit in the chambers of the Foraminifera than to the appropriation of its material by the living animals in the formation of their shells. That deposit may have had the character, in the first instance, of either the green or the ochreous silicate of alumina and iron, which constitutes the material of the internal casts, and may have been subsequently changed in its character by a metamorphic action analogous to that which changes felspar into clay. That the presence of an excess of carbonic acid would have an important share in such a metamorphosis appears from the fact, long since brought into notice by Sir Charles Lyell*, of the disintegration of the granite in Auvergne and of the gneiss in the alluvial plains of the Po where subject to its influence. And the same agency (especially when operating under great pressure) would be fully competent to effect the removal of the calcareous shells, as was distinctly pointed out nearly thirty years ago by Prof. W. C. Williamson in his classical memoir on the Microscopic Organisms of the Levant Mud†. This seems to me the most probable mode of accounting for their disappearance from a deep-sea deposit, where no mechanical cause can be invoked. But in shallower waters, where the same excess of carbonic acid does not exist, and the aid of pressure is wanting, but where a movement of water over the bottom is produced by tides and currents, I am disposed rather to attribute the disappearance of the shells to mechanical abrasion, having noticed, in Capt. Spratt's Ægean dredgings, that many of the shells were worn so thin that the coloured mineral deposit in their interior could be seen through them—which was, in fact, what first drew my attention to its presence. This is the explanation I should be disposed

* Principles of Geology, 11th ed., vol. i. p. 409.

† Memoirs of the Literary and Philosophical Society of Manchester, vol. viii. p. 98.

to give of the disappearance of the shells from the green sand brought up by the 'Challenger' in the course of the Agulhas Current; but whether it was mechanical abrasion or chemical solution that removed the Foraminiferal shells whose internal casts formed the Greensand deposit of the Cretaceous epoch, must remain for the present an open question*.

February 11, 1875.—Joseph Dalton Hooker, C.B., President, in the Chair.

"On the Structure and Development of *Myriothela*." By Prof. ALLMAN, F.R.S.

The *endoderm* of the body is composed of numerous layers of large spherical cells composed of clear protoplasm, enclosing a nucleus with some brown granules and refringent corpuscles. Externally it is continued in an altered form into the tentacles, while internally it forms long thick villus-like processes which project into the cavity of the body. Towards the free ends of these processes there are abundantly developed among the large clearer cells, smaller, easily isolated spherical cells, filled with opaque brown granules. Where the endoderm passes into the tentacles it loses its large clear-celled condition, and consists of small round cells, so loaded with opaque granules that the axis of the tentacle appears nearly white under reflected light.

The free surface of the endoderm carries, at intervals, long, very slender, sluggishly vibrating cilia, and is overlaid with a thin layer of homogeneous protoplasm, which on the villus-like processes becomes especially distinct, and which here develops minute mutable pseudopodia, which are being constantly projected and withdrawn. Indeed the vibratile cilia appear to be but a modification of these pseudopodial processes of protoplasm.

Interposed between the endoderm and the ectoderm is the *fibrillated layer*. It is extremely well developed, and consists of longitudinal muscular fibrillæ, closely adherent to the outer surface of a structureless hyaline membrane—the "Stützlamelle" of Reichert. The fibrillated layer, with its supporting membrane, is so strong as to remain entire in a section of the animal after the tissues on both sides of it have been broken down.

The *ectoderm* is composed of two zones, a superficial and a deep. The superficial zone consists mainly of two or three layers of small round cells containing yellowish granules. Among these cells the thread-cells may be seen, lying chiefly near the outer surface of the body. Two forms of thread-cells may be here di-

* It is due to Prof. W. C. Williamson to point out that, in the Memoir already referred to, he indicated the probability "that many of our European Greensands, and other siliceous strata, however barren of such structures they appear, may have once contained multitudes of calcareous microscopic organisms, some of which have been removed *after* the consolidation of the strata, either leaving hollow casts, or having had the cavities subsequently filled with silica."

stinguished—one ovate, with the invaginated tube occupying the axis; the other fusiform, with the invaginated tube oblique.

The deeper zone of the ectoderm consists of a very remarkable tissue, composed of peculiar membraneless cells, each of which is prolonged into a tail-like process, so that the cells assume a claviform shape. In most situations, where this tissue is developed, the processes from several such cells unite with one another, so as to form branching, somewhat botrylliform groups, whose common stalk can be followed into the fibrillated layer. The author is thus enabled so far to confirm the observations of Kleinenberg on cells of apparently the same significance in *Hydra*. In *Myriothela*, however, these cells do not, as in *Hydra*, reach the surface. With the exception, apparently, of their condition in the transitory arms of the *Actinula* or locomotive embryo, they form everywhere a deep zone interposed between the muscular layer and the superficial layer of the ectoderm. This zone is designated by the author as the zone of *claviform tissue*. Though it is in intimate association with the fibrillated layer, the author did not succeed in tracing a direct continuity of the individual fibrillæ with the processes of the cells (as described by Kleinenberg in *Hydra*).

The author adopts, as a probable hypothesis, the views of Kleinenberg respecting the caudate cells of *Hydra*, which he regards as representing a nervous system. While the deep layer of ectodermal cells in *Myriothela* would thus constitute a nervous layer, the superficial layer would represent an epidermis; and since recent researches justify us in regarding the ectoderm and endoderm of the Cœlenterata as respectively representing in a permanent condition the upper and lower leaf of the blastoderm in the development of the higher animals, we should thus find *Myriothela* offering no exception to the general law, which derives both epidermic and nervous tissues from the upper leaf of the blastoderm.

The structure of the tentacles is in the highest degree interesting. In their narrow stalk-like portion, the condition of the endoderm departs widely from that of this tissue in the tentacles of other marine hydroids; for it presents no trace of the septate disposition so well marked in these. It is, on the contrary, composed of a layer of small cells loaded with opaque granules and surrounding a continuous wide axile cavity.

It is, however, in the terminal capitulum of the tentacle that the structure of these organs departs most widely from any thing that has as yet been recognized in the tentacles of other hydroids. Here a very peculiar tissue is developed between the muscular layer and the proper ectoderm, where it takes the place of the zone of claviform tissue. It forms a thick hemispherical cap over the muscular lamella and endoderm of the tentacle, and is composed of closely applied exceedingly slender prisms, with their inner ends resting on the muscular lamella, to which the prisms are perpendicular, the whole structure forcibly suggesting the rod-like tissue associated with special sense-apparatus in higher animals. It appears to be but a modification of the tissue which elsewhere forms the zone of claviform tissue.

Extending in a radiating direction from the convex surface of this rod-like tissue, towards the external surface of the tentacle, may be seen numerous firm filaments, each of which, making its way among cells of the ectoderm, terminates distally in a very delicate transparent oviform sac, which carries, near its distal end, a minute styliform process. Within this sac, and completely filling it, is an oviform capsule with firm transparent walls, and having immersed in its clear refringent contents a cylindrical cord wound upon itself in two or three coils. Under pressure, the contained cord may be sometimes forced out through the smaller or distal end of the capsule. Notwithstanding the obvious resemblance of these bodies to thread-cells, their significance is, without doubt, something entirely different. Indeed their resemblance to the Pacinian bodies of Vertebrata is too strong to be overlooked. Their assemblage constitutes a zone parallel to the spherical surface of the capitulum, and lying at a slight distance within it. Though it is impossible to assign to them, with certainty, their exact function, we feel compelled to regard the whole system, including the bacillar tissue to which their stalks can be traced (and which is only a locally modified portion of the nervous zone, or zone of claviform tissue), as an apparatus of sense. It would almost seem to represent a form of sense-organ, in which sight and touch show themselves in one of their earliest phylogenetic stages, in which they have not yet become fully differentiated from one another. This is the only known instance of the existence in a hydroid trophosome of any thing which may with fair reason be regarded as a special apparatus of sense.

The male and female sporosacs are borne by the same trophosome.

The generative elements, whether male or female, originate in a special cavity (gonogenetic chamber), which is formed in the substance of the endoderm of the sporosac.

In the female, the primitive plasma becomes gradually differentiated into a multitude of cell-like bodies having all the characters of true ova with their germinal vesicle and spot. They are entirely destitute of enveloping membrane.

These bodies next begin to coalesce with one another into numerous roundish masses of protoplasm, which develop over their surface minute pseudopodial retractile processes.

The masses thus formed still further coalesce with one another; and there results a single spheroidal plasma-mass, through which are dispersed numerous small spherical vesicles, mostly provided with a nucleus. These vesicles appear to be nothing more than the nucleolated nuclei of the coalesced ovum-like cells.

About the time of the completion of this last coalescence, the resulting plasma-mass, enveloped in an external, very delicate, structureless membrane, is expelled, by the contraction of the sporosac, through an aperture formed by rupture in its summit.

Immediately after its expulsion, it is seized, in a manner which forcibly suggests the supposed action of the Fallopian tube on the mammalian ovum at the moment of its escape from the Graafian follicle, by the sucker-like extremities of certain remarkable bodies, to which the author gives the name of *claspers*, which are developed among the blastostyles, and resemble long filiform and very contractile tentacles.

It is apparently now that fecundation is effected; for the plasma becomes again resolved into a multitude of roundish masses. This phenomenon may be regarded as representing the yelk-cleavage of an ordinary ovum. Reasons are assigned for believing that it is through the agency of the claspers that fecundation takes place; and the claspers are compared to the hectocotylus of Cephalopods, and to certain organs by which fecundation is effected among the Algæ.

The mulberry-like mass thus formed, surrounded by its structureless membrane, which has now acquired considerable thickness and forms a firm capsule, continues to be held in the grasp of the claspers during certain subsequent stages of its development. An endoderm and ectoderm with a true multicellular structure become differentiated, a central cavity is formed by excavation, and the germ becomes thus converted into a spheroidal non-ciliated *Planula*. This, after acquiring certain external appendages, ultimately escapes, by the rupture of the capsule, as a free actinuloid embryo.

The actinuloid, on its escape from its capsule, is provided not only with the long arms already noticed by Cocks and Alder, but with short scattered clavate tentacles. The short clavate tentacles become the permanent tentacles of the fully developed hydroid; the long arms, on the other hand, are purely embryonic and transitory.

The long embryonic arms originate in the spheroidal *Planula*. They are formed by a true invagination, and at first grow inwards into the body-cavity of the *Planula*. It is only just before the escape of the actinuloid from its capsule that they evaginate themselves and become external.

After enjoying its free existence for one or two days, during which it moves about by the aid of its long arms, the embryo fixes itself by its proximal end, the long arms gradually disappear, the short permanent tentacles increase in number, and the essential form of the adult is soon acquired.

MISCELLANEOUS.

On Pinaxia. By Edgar A. Smith, F.Z.S., Zoological Department, British Museum.

This genus was formed by Mr. A. Adams (Proc. Zool. Soc. 1853, p. 185) for the reception of a little shell said to have been found at the Philippine Islands by Mr. Cuming, and described under the